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**Common Knowledge: Examining the Illusion of Explanatory Depth in Transactive
Memory Systems**

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Abstract

The Illusion of Explanatory Depth (IOED) describes an often-held belief that we understand and can explain complex causal relations better than we in fact can. Previous findings identified the IOED resulted in individuals but not in small transactive memory systems. The current study continued investigating the IOED in small transactive memory systems (TMS) to understand mechanisms which may underpin this, through an online experiment. 76 participants, 38 pairs of non-stranger dyads completed either the collaborative or nominal condition of the experiment. In the collaborative condition dyads completed the experiment together, nominal dyads completed it alone. Participants rated their own, their partner's and their combined knowledge of bicycles on a scale of 1-10, before and after, completing two tasks requiring their knowledge of bicycles. Dyads in the nominal condition completed the tasks alone, dyads in the collaborative condition completed the task collaboratively. Participants were also asked to rate their confidence in their knowledge ratings and were timed how long they took to make ratings. Contrary to most IOED research, individuals self-assessed post-task knowledge ratings were higher than pre-task knowledge ratings. This increase in participant's ratings occurred in knowledge ratings made about the self, their partner, and their combined knowledge as a dyad, despite considerable error rates. Participants showed low confidence in partner knowledge ratings, and equally high confidence in both self and dyad knowledge ratings. A correlation between both dyad pre- and post-task ratings and errors was found in nominal groups. This might tentatively suggest participants experienced a feeling of fluency and possible accuracy when assessing their shared knowledge held within the TMS. Future research could focus on how communication influences people's predictions about performance of the dyad.

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Common Knowledge: Examining the Illusion of Explanatory Depth in Transactive Memory Systems

“The only true wisdom is in knowing you know nothing”.

Socrates

Many people believe to have a greater understanding of the world than they in fact do, only once confronted with the limitations of their knowledge, do they become aware of this. This is a well-established phenomenon, known as the Illusion of Explanatory Depth (IOED). It demonstrates individuals consistently overestimate their understanding of, and ability to explain, various concepts including tools, policies, and broad scientific theories (Alter, Oppenheimer, & Zemla, 2010; Keil, 2003; Keil, 2012; Lawson, 2006; Mills & Keil, 2004; Rozenblit & Keil, 2002; Sloman & Fernbach, 2017; Vitriol & Marsh, 2018). One proposed explanation for the IOED, is that people typically access knowledge and make explanations in a supported social environment. When required to make judgements alone, they may mistakenly draw upon memory of what they can achieve in a supported social environment. People may be under an illusion that what they can achieve in a supported social environment, reflects what they can achieve on their own (Sloman & Fernbach, 2017). There is however little to no research supporting this theoretical explanation.

This prompted the present study's effort to explore a link between two seemingly distinct fields, the IOED literature and transactive memory system literature. Transactive memory system (TMS) theory describes a mechanism where people benefit from a system in which they share the encoding, storage, and retrieval of information in small groups (Wegner, 1986). In developing such a system, it predicts memories recalled by individuals in the TMS will be more than the sum of the individual memory, either in amount or quality of information recalled. There exists an intuitive sense that there are benefits to collaborating and many proverbs exist to describe this. Such as “two heads are better than one”, “a problem shared is a problem halved”, “Ehara taku toa, he takitahi, he toa takitini” *My success should not be bestowed onto me alone, as it was not individual success but success of a collective.* The present study aimed to examine this principle; are two heads really better than one? By examining how individuals assess and utilise shared knowledge. And might the IOED be overcome with access to a socially supported knowledge environment? x

While these fields of research appear separate, on examining the theory and current literature base of each, there are clear parallels that suggest researching them together will be beneficial. Previous research completed by Rozenberg (2021) initiated this connection. The overall aim of the present study is to continue examining the proposed theoretical connection

between these two fields, while also contributing to the literature and understanding of each. In the following pages, the two fields of literature, IOED and TMS will be discussed further.

Illusion of Explanatory Depth

“To know what you know and what you do not know, that is true knowledge”.

Confucius

Philosophers of Ancient Greece and China understood the wisdom in knowing the limits to one’s own knowledge. Despite this, Wilson and Keil (1998) appear to be the first to examine peoples’ ability to explain the world around them, in their founding paper “The Shadows and Shallows of Explanation”. This paper is a philosophical approach to analysing explanations and people’s apparent poor ability to do so with much depth. Given a successful explanation is described as giving details or reasons that increase the understanding of a phenomenon. Wilson and Keil (1998) explore how despite explanations being pervasive and significant throughout human life, culture and historical periods, they are surprisingly shallow.

Keil explores the idea of folk science in later papers Keil (2003, & 2012) in which he describes the intuitive theories laypeople use to explain the world. These intuitive theories of knowledge or folk theories give only a very poor representation of any mechanistic knowledge, often far worse than individuals are aware. Wilson and Keil (1998) describe a “theoretical abyss” existing between the ability to provide brief explanations that are sufficient for navigating life and having a comprehensive understanding, which allows a more in-depth explanation. To describe this Wilson and Keil (1998) draw upon Putnam’s (1975) notion of linguistic division of labour, in which there exists a division between experts and laypeople. A layperson likely knows enough about what Wilson and Keil (1998) refer to as the “nominal essences” of things they interact with to be able to offer relatively shallow explanations. Whereas an expert can provide richer, more in-depth explanations. Although individuals are faced with the theoretical abyss as the norm, the theoretical knowledge that is lacking in them, exists in that of experts. Thus, to cope with a complicated theoretical world, people have enacted a form of distributed cognition in the form of the division of cognitive labour.

Wilson and Keil (1998) hypothesise laypeople have this “nominal essence” of the knowledge which experts hold, in shallow or superficial way, that allows them to have an idea of explanations in a knowledge domain without holding extensive detail. This they argue may be central to understanding how explanation works in broader social contexts. Sloman

and Rabb (2016) explore this idea and found just knowing that others understand a subject gave participants a sense of understanding, however this was shattered by their later failure to explain the subject. People rely on knowledge in others extensively in their explanatory endeavours and likely rely on the assumption of knowledge in others, to give them a sense of explanatory insight. This reliance on community is a form of division of cognitive labour, which is a critical, prominent part of everyday explanation.

Wilson and Keil (1998) describe a means to overcoming this shallowness of explanation by accessing a web of knowledge. This web of knowledge includes a network of domain experts who hold theoretical knowledge of the subject required to make a richer, more in-depth explanations. These networks may be accessed by both experts and laypeople, in this way laypeople who are able to make do with a superficial understanding only do so, because experts exist who hold a far greater depth of knowledge. One account of the illusion laypeople are under, is that people confuse their own understanding with that of experts and are not aware of the extent to which they rely on everyday access to this web of knowledge. It is not until they are asked to explain alone, do laypeople become aware of this illusion.

Wilson and Keil (1998) are clear in that no one may be an expert or have access to expert webs of knowledge in all matters. Sloman and Fernback (2017) argue intelligence resides not in the individual but in the collective mind and when put together human intelligence is impressive, but it is a product of community, not any one individual. To function, individuals rely not only on knowledge stored within their heads but also on knowledge stored elsewhere: in their bodies, in the environment, and in other people. While there may be rationale for distributed cognition, people appear to be disillusioned in their limited capacity to explain phenomenon to any depth alone.

If, as it appears suggested in the literature, the IOED is partly due to individuals making knowledge judgements in social contexts more often than alone. Then without being of aware of this reliance, fail to distinguish between knowledge held by them, from knowledge held in their community. The theoretical abyss could then be described as existing within an individual who does not or cannot reach out to their social distributed web of knowledge. The present study aims to address this by examining this illusion in transactive memory systems, where it is suggested, people may access their web of knowledge.

Experimental research examining the Illusion of Explanatory Depth

Following Wilson and Keil (1998) principal paper, an area of research developed that has been explored across many domains, including politics, natural phenomenon, artifacts,

and narratives (Lawson, 2006; Keil, 2003; Vitriol & Marsh, 2018). It appears that people of all ages are susceptible to this illusion, Mills and Keil, (2004) found children as young as 7-8yrs showed IOED in explanatory knowledge but not procedural knowledge. In the typical IOED testing paradigm, participants are asked to initially rate their understanding of how a phenomenon or object functions. They are then asked to explain the phenomenon or object in detail or utilise their knowledge of that phenomenon to complete a task. For a second time and in the same manner, participants are again asked to rate their understanding of how the phenomenon or object functions. This act of having to provide an explanation is thought to expose their limited understanding, and subsequently, participants typically display a reduction from pre to post self-reported understanding.

The IOED is now a well-established phenomenon depicted in many studies. A primary and widely cited paper in the IOED field is that by Rozenblit and Keil (2002), *The misunderstood limits of folk science: An illusion of explanatory depth* paper. Rozenblit and Keil (2002), completed 12 studies together looking at the IOED across knowledge domains and exploring possible mechanisms behind the initial overconfidence.

They propose several possible features of explanatory or theory like knowledge make it susceptible to this illusion compared to other types of knowledge such as facts, procedures, and narratives. One such feature that may contribute to an IOED, is a confusion between what knowledge is stored in one's head and what one is capable of deciphering in the present, upon inspection of a problem or object with access to information in real time (Rozenblit & Keil, 2002). When problem solving, people may expect the information required to be readily available thus utilising the physical and social structure of the world far more than they realise.

Furthermore, explanatory knowledge has no discrete ending or clear right or wrong answer which is universally sufficient. There are continuing levels of analysis of which one could explain complex causal concepts. The iterative nature of explanatory knowledge may contribute to the IOED, as the feeling of insight may be misinterpreted for a deeper knowledge (Rozenblit & Keil, 2002). Another feature of explanatory knowledge that may contribute to the IOED is people typically have less experience challenging the depth of their explanatory knowledge. As there isn't a clear end to having completed explaining a topic, it is also more difficult to assess one's competence. In contrast, establishing if one knows a fact is relatively simple and people appear to be better calibrated to assessing their knowledge of semantic concepts such as facts and trivia. Rozenblit and Keil (2002), examined how the IOED appears to be separate from pure over confidence and other illusions using several

methods. Their first 4 studies displayed an IOED (a drop from pre- to post-task ratings) in explanatory knowledge. If this was exclusively a result of overconfidence, one would expect this same effect to also be demonstrated in facts and procedural knowledge. However, there was significantly less of a drop between pre- and post-task ratings for knowledge of facts and in contrast a slight increase in knowledge ratings for procedural knowledge. Other illusions such as the judgement of learning is limited by its focus on predictions for recently learned information, such as pairs of words, lists of items (Mills & Keil, 2004). The specificity of the overconfidence, that there is such a large illusion in explanatory knowledge but not across other knowledge domains suggests it is different to traditional overconfidence. Rozenblit and Keil (2002) used independent participants to rate other's explanations, these independent ratings were much closer to the participants later knowledge ratings than the initial ratings. This supports the idea participants were becoming more accurate at assessing their knowledge, not purely less optimistic or conservative when confronted by the experiment. Additionally, following the typical IOED experimental paradigm, Rozenblit and Keil (2002) provided participants an expert's explanation of the task, then asked participants how well they understood the concept now. Participants consequently showed a rise in knowledge ratings, suggesting the IOED ratings weren't lowered due to feeling despondent or general drop in confidence. They also asked participants how surprised they were by how much or how little explanatory knowledge they were able to produce, many reported genuine surprise and new humility at how little they knew.

Following on from Rozenblit and Keil's (2002) seminal study, the IOED has been demonstrated in several studies highlighting real-world implications. One such study is that by Fernbach, Rogers, Fox and Sloman (2013) in which they assessed the implications of the IOED in political extremism. They found participants showed a typical drop in post-task knowledge ratings, after being asked to generate mechanistic explanations of political policies. Following the explanatory task, participants reported more moderate political positions and associated behaviour change, that is they were less likely to donate to relevant advocacy groups. Importantly, no such change in political extremity was seen in participants who were asked to give reasons for their policy choices rather than an explanation. Both studies by Alter, Oppenheimer and Zemla (2010) and Vitriol and Marsh (2018) found evidence of the IOED in the political domain. Vitriol and Marsh (2018) found a political IOED but not non-political IOED was associated with increased support for both political and non-political conspiracy beliefs.

Fisher and Keil (2016) examined whether formal expertise reduced the IOED. Participants were found to accurately self-assess in areas outside of their expertise, that is those with more education accurately assessed their level of knowledge in topics outside of their field of study. However, they overestimated their ability and displayed an IOED when attempting to explain topics within their field of expertise. This was suggested to be contributed to by a failure to recognise the degree to which previously held knowledge had been forgotten over time. There are serious potential consequences to this illusion existing in professionals such as medics. Fisher and Keil (2016) suggested experts may fail to recognise how much knowledge is lost over time due to unknowingly, relying upon external sources of knowledge to fill these knowledge gaps. This may support the theoretical prediction the IOED may be overcome with access to an TMS and web of knowledge.

Fisher and Oppenheimer (2021) looked at the impact of outside assistance on participants illusions of knowledge. Participants were put into three groups, those that received no help, delayed help and immediate help answering questions. Those who had help estimated their future performance would be much higher than those who received no help, appearing to fail to recognise the extent to which help contributed to their success. Receiving delayed help appeared to mitigate the self-reported future ability, however, it didn't entirely mitigate the effect. Fisher and Oppenheimer (2021) hypothesised that those who receive delayed assistance may attempt the task, realising its difficulty and therefore become aware of the gaps in their knowledge.

Interesting research examining the IOED and reliance on external sources is that concerning the internet. Fisher, Goddu, and Keil, (2015), examined the impact accessing the internet to answer questions, had on self-reported estimates of knowledge. They found participants who accessed the internet to answer questions, later rated themselves as significantly better at giving explanations in unrelated domains, than participants who didn't access the internet. Fisher et al. (2015) hypothesised people mistook the easily accessible information from the internet with knowledge that was held 'in the head'. In this study the authors theorised the internet was acting as a TMS for participants. In the present study, the IOED will be examined within person-to-person TMS systems.

The current literature highlights how the IOED occurs in individuals across domains which have very real-world consequences. There exists a theoretical explanation for the IOED which highlights how explanatory tasks are regularly carried out in a social context with access to knowledge held outside of the individual. Given the potential serious consequences of the IOED, this study aimed to examine the IOED in participants who had

access to socially distributed knowledge. The next section will discuss transactive memory systems, which is well-suited theory within which to examine this idea.

Transactive Memory Systems

Wegner, Giuliano and Hertel (1985) describe the theory of a transactive memory system as “a set of individual memory systems in combination with the communication that takes place between individuals”. It was first developed in response to group mind theory falling out of favour during the behavioural revolution in psychology at the time. Central to this theory and perhaps what sets it apart from previous group mind theories is the importance of interpersonal communication, ensuring an exchange or transaction of information occurs between individuals.

Transactive memory system theory sees others act as the external memory storage for individuals. An individual has access to the others internal memory; however, the interdependence and corresponding communication produces a knowledge holding system that is larger and more complex than the sum of individuals own memory systems. TMS allows individuals to distribute cognitive labour by allocating different types of information processing to each partner. Critical components of a TMS are the memories or information that each or all hold, their individual or group understanding of who knows what, and the ability to communicate to effectively to share this.

Components of a transactive memory system can be considered as, the individual’s memory and how it becomes connected to or shared with others. Just as an individual’s memory are commonly understood to occur in 3 stages; encoding, storing and retrieval of information, so too does a transactive memory system. The transactive nature or the communication between individuals within the shared system is evident and essential at these three stages for success. In transactive encoding, individuals can be seen to discuss incoming information to ascertain who and how the new information can be stored. Storage is distributed between group members in an efficient way that relates to their expertise and role in the group. Retrieval occurs when the dyad works together to retrieve the uniquely held information. When one person in the system requires knowledge, they can retrieve it from the expert in this domain rather than searching for it themselves, saving time and energy. In cases where there is no expert, the individuals within the system may cue each several times, finding related information instead, prompting each other until successful retrieval occurs. Thus, retrieval is not due to either individual alone but to the combined transaction between individuals, resulting in more than a simple aggregation of individual recall.

Wegner (1986) suggests this system is beneficial to the individuals and that as a group a transactive memory system can outperform the sum of their parts. The theory suggests when each member specialises in certain domains, the overlap of expertise is reduced, and all members have access to a greater pool of information across different domains than they would otherwise. Each group member would hold different pieces of lower order information relevant to a topic, and in an efficient transactive memory system can access and combine this information to create a more complete group memory than any individual could access alone.

Transactive memory system theory was initially created to describe the specialised cognitive division processes within intimate dyads (Wegner, 1986). A transactive memory system develops over time as group members become acquainted and learn about each other's skills, knowledge, and expertise. However, time alone is not a good predictor of what makes a successful TMS. Rather a set of behaviours; memories or info that each member holds, individual and group understanding of who knows what and ability to communicate to effectively share this information (Barnier, Klein & Harris, 2018). More recent reviews of Wegner's transactive memory system theory, have been completed by the likes of Hubner (2016) and Peltokorpi & Hood (2019). These reviews both advocate and suggest avenues for future research, including a redirection to examining TMS in dyads and real-world circumstances.

Experimental research examining Transactive Memory Systems

There is conflicting research in the TMS field regarding benefits of collaborating which this section will aim to explore. As TMS theory predicts there are multiple components of the TMS which modifies the benefits of collaborating. Since its inception a significant focus of the TMS research appeared to move away from couples to large organisational groups (Barnier, Klein, & Harris, 2018). However, core features of TMS are missing at organisational level: large and difficult to identify who knows what, less communication across boundaries, geographically distributed and rely on technology to communicate.

Perhaps surprisingly, despite benefits of shared remembering predicted by transactive memory theory, research on collaborative recall predominantly demonstrates shared remembering has costs for recall, termed collaborative inhibition (Harris, Keil, Sutton, Barnier & McIlwain, 2011). Intuitively one might think grouping people together would result in greater success, such is the saying "two heads are better than one". This sentiment appears to be true across collaborative memory research, however what is contested is

whether two heads together are more successful than two heads apart. The collaborative recall paradigm was established to measure the consequences of remembering in groups, in which collaborative and nominal groups are compared. Nominal groups are the pooled performance of the same number of people in the compared collaborative group, creating an artificial group (Harris, Barnier, Sutton, & Keil, 2014). This method of comparison allows researchers to test whether individual recall is more than the sum of its parts, and which informed the design of the present study.

Collaborative inhibition is reliably evidenced in numerous experiments, in which the performance of nominal groups is significantly better than collaborative groups. Marion and Thorley (2016) conducted a meta-analytic review of collaborative inhibition and found the following factors increased collaborative inhibition; remembering in large groups, retrieval of uncategorized content, free flowing procedures and group members who didn't know each other. These factors describe components also described in TMS theory, as modifying the benefits of collaborating.

The retrieval strategy disruption hypothesis is the most widely cited theoretical explanation for why collaborative groups remember less than nominal groups (Basden, Basden, Bryner & Thomas, 1997). This hypothesises collaborative groups may have idiosyncratic retrieval strategies, some groups may have optimal retrieval strategies, where individuals recall different information, possibly cueing each other to do so, resulting in greater total recall. Alternatively, when collaborative group members attempt to recall information using different retrieval strategies, individuals are exposed to other's methods, perhaps disrupting their own methods of retrieval, and productivity of the group suffers. As noted earlier, Marion and Thorley (2016) found the extent of disruption appears to be mediated by several factors, group size and relationship of group members being two of them. Group size may increase collaborative inhibition because there is an increased likelihood of the presence of greater numbers of conflicting retrieval strategies. Social relationships appear to influence collaboration as it is increased in strangers than known groups. One explanation is some close relationships have developed a transactive memory system, in which they utilise complementary rather than conflicting retrieval strategies.

Thus, collaborative inhibition doesn't appear to be an inevitable consequence of joint remembering, rather certain features of interaction appear to influence the success of collaboration. Research showing collaborative inhibition may have predominantly focused on stranger groups, in contrast to individuals who have pre-existing relationships. Wegner, Erber and Raymond (1991) tested stranger and non-stranger dyad's ability to memorise lists of

words, relating to different domains of expertise. Some pairs received instructions regarding who was responsible for recalling which categories, while other pairs received no such instruction. When no instructions were provided during the learning phase, non-stranger couples recalled more, however when instructions were given, stranger pairs did best. It seems a prior relationship facilitates recall only when dyads can rely on existing transactive memory system already in place.

Collaborative facilitation, where collaborative groups outperform nominal groups is found in several studies such as that by Harris, Barnier, Sutton, and Savage (2019). In which they conducted a study of long-married couples, and found a subset of couples who overcame collaborative inhibition and collaborated effectively when recalling personally relevant information. Those who used beneficial communication strategies (only found by assessing recordings of discussion) such as cuing and repeating each other showed collaborative facilitation rather than inhibition. In this study Harris et al. (2019) argue collaborative inhibition effects are primarily shown in research where strangers are asked to recall relatively meaningless stimuli. Harris et al. (2011) also examined collaborative remembering in older couples, and found certain strategies were associated with collaborative facilitation, the use of shared strategies for recall and successful cross-cuing. Harris et al. (2011) draws upon Wegner et al. (1991), theory of TMS and identified their findings as support for finding collaboration facilitation in the environment of a successful TMS. Harris et al. (2011) identified further research was required to examine collaborative recall within TMS. Meade, Nokes and Morrow (2009) examined communication between pilots. Interestingly, they found expert pilots recalled more about aviation scenarios when they collaborated than when they recalled alone, whereas novice pilots showed collaborative inhibition. Despite these expert pilots being strangers to each other, they did however share a technical knowledge as well as extensive training in effective communication.

An additional factor which may influence collaborative recall performance is the quality of the relationship between partners. Condon, Ritchie and Igou (2015) found self-reported levels of familiarity and trust between two partners to be associated with memory conformity in recall of a witnessed event both in negative sense (adopting each other's errors) and positive sense (pruning each other's errors). Eyewitness recall is a growing area of research which has found collaborative facilitation. In a study by Vredeveldt, van Deuren and van Koppen (2019) both nominal and collaborative groups were interviewed three times. They found regardless of whether participants were acquainted or not, collaboration did neither inhibit nor facilitate recall. However, collaborating (pairs) recalled more new accurate

information in the final interview, (evidence of post collaborative benefits) and significantly less incorrect information (evidence of error pruning and cross cuing) than nominal pairs. Interestingly they found neither a longer relationship nor a better relationship improved collaborative recall performance. Vredeveltdt, Groen, Ampt and Koppen (2017) looked at the costs and benefits to eyewitness recall in collaborative and nominal pairs. Vredeveltdt et al. (2017) found collaborative pairs recalled as much as nominal pairs however also made significantly fewer errors.

As several studies discussed have suggested, there is a continued need to examine how remembering and collaborating within well-established groups might be beneficial. As Harris et al. (2014) highlights, it is socially and within groups that most remembering occurs. The present study aims to further this research by providing insight about the mechanisms and functions of individual and shared remembering.

Research informing the design of the present study

Three studies predominantly influenced the design of this study, these were that by Lawson (2006), Rozenblit and Keil (2002) and Rozenberg (2021). Rozenblit and Keil (2002) seminal study was discussed previously, the 12 studies they carried out provided a clear foundation for an empirical framework that uncovers an IOED in individuals and shaped the IOED testing paradigm, which this study will follow. Implicated in this study is their finding that the degree of casual transparency of a system, that is the ratio of visible to hidden parts, is a critical factor behind a significant IOED. Perhaps when utilizing the environment to solve problems, people underestimate how much they work through the problem in vivo rather than retain all the details. Perhaps this is partly why Lawson (2006) used the bicycle as her medium for testing the IOED, as well as it being a familiar and relatively simple object. The present study will follow a similar experimental paradigm to that of Lawson's (2006). Lawson (2006) asked participants to first rate their knowledge of a bicycle on a 7-point scale, then complete a schematic drawing of a bicycle by adding the pedals, chain and extra sections of frame as displayed in Figure 1. Participants then answered 3 forced choice questions in which they selected the picture depicting the correct position of the pedals, chain and extra frame. This was included to check drawing errors were not due to a difficulty sketching. Finally, participants were asked to rerate their knowledge of a bike on the same 7-point scale.

First, please can you rate your knowledge of how bicycles work on a scale from 1 to 7 where 1 means “I know little or nothing about how bicycles work” and 7 means “I have a thorough knowledge of how bicycles work”. You do not need to be an expert to give yourself a “7” rating—an expert would be rated as 7++. Also, you should rate how much you know, not how much you think you know compared to other people. **Rating:** _____



Second, as best you can, please fill in on the above schematic bicycle drawing the main bits of the frame of the bicycle that you think are missing, the pedals and the bicycle chain. Use the symbols given on the right of the drawing to show the frame, pedals and chain.

Figure 1. Schematic drawing of the bicycle task from Lawson, R. (2006). The science of cycology: Failures to understand how everyday objects work. *Memory & Cognition*, 34(8), 1667-1675. doi:10.3758/BF03195929

Lawson (2006) found participants regularly made drawing errors, placing the pedals, chain and frame in arrangements that would negatively impact the functioning of the bicycle. Those who weren't bicycle experts showed the typical reduction in post-test rating compared to pre-test of an IOED study. Participants who altered their ratings did so depending on whether they did poorly on the task, indicating people have some insight into their own performance. Of interest is an expert participant group (88% cycled at least weekly) in Lawson (2006), understandably made fewer errors than non-experts, however still made errors.

As presented, there is clear empirical evidence for the existence of the IOED within individuals. Underlying several of the above mentioned IOED studies, is a theme of individuals being unknowingly reliant on outside assistance. Hence, one explanation for the IOED being people confuse a sense of knowledge being held in others, for holding that knowledge themselves, as Wilson and Keil (1998) described. Sloman and Rabb, (2016) supported this with showing participants reported a greater sense of understanding of a phenomenon if experts understand it, but crucially, only if they have access to these experts. This has clear parallels to TMS theory, which describes the division of cognitive labour

within groups and experts. Interestingly, there is however minimal research of IOED in Transactive Memory systems, which Rozenberg (2021) begun to address.

Rozenberg (2021) examined IOED's in the context of TMS to examine the idea IOED's are a consequence of knowledge being held in a socially distributed cognitive system. Crucially Rozenberg (2021) found evidence of the IOED in individual knowledge ratings, however not in partner or dyad knowledge ratings. Rozenberg's (2021) findings gave additional rationale for continued exploration of the IOED in TMS. Rozenberg's (2021) study was a within subjects design, dyads completed the experiment twice, once individually and a second time together. Given all participants completed the experiment first alone, then together there existed a possible learning effect. The present study aims to replicate and build on Rozenberg's (2021) research through a between subjects design, comparing collaborative and nominal groups. This allows examination of how "accurate" participants are when accessing a TMS. Rozenberg (2021) examined individual pre-task self ratings with post task collaborative ratings. The present study will instead be examining how self, partner and dyad ratings change in collaborative and nominal groups. A transactive memory system will be assumed to exist with the pairs recruited for the present study. The correlation between ratings and performance in collaborative and nominal groups, will also be examined.

The present study will examine how individuals make decisions about their own knowledge, knowledge held by their partner and knowledge within their dyad. This is to identify if individuals can recognise the limits of the knowledge held within their TMS more accurately than they can recognise their limits as an individual. To examine this and possible different decision-making processes that may account for Rozenberg's (2021) findings, two additional components are included in this IOED experimental paradigm: confidence ratings and timing of decisions. These two components were introduced because Keil (2012) suggests people's intuitive theories for the world help them seek out experts to bridge their knowledge gaps. As lay people's intuitive theories are so poor, he suggests it is with heuristics people make limited casual relations and evaluate experts and their knowledge. If as Keil (2012) suggests, people are using heuristics to examine explanatory knowledge, it will be informative to examine confidence and timing. Heuristics are mental shortcuts that allows people to solve problems and make judgements quickly and efficiently. These are rule-of-thumb strategies to shorten decision making time and allow people to function efficiently without constantly stopping to think about their next course of action. They are helpful, as one is required to make hundreds of decisions a day, but they may also lead to cognitive bias. Given it could be said, it would be inefficient as well as impossible to have

robust explanatory knowledge in all domains, they may be benefits to having shallow explanations. Keil (2003) suggests feelings of insight when attempting to understand the world, may provide a constraint to the impossible task of having a deep understanding in across many domains. Perhaps, individuals rely on fast gut feeling judgements for assessing their own knowledge and more on slower considered judgements about others.

There are several possible heuristics that have influenced the inclusion of confidence ratings and timing. According to the confidence heuristic, when people communicate beliefs to one another, they generally express confidence in proportion to their degree of certainty, based on their relevant knowledge. If they have common interests in coordinating their decisions, recipients tend to judge the persuasiveness of the communication according to the confidence with which it is expressed (Pulford et al., 2018). Bahrmí et al. (2010) proposed that instead of communication reliability, individuals communicate their confidence in a decision or judgement as a unit free proxy of estimated reliability. This study will measure confidence of knowledge ratings as it may give insight into possible different decision-making processes contributing to the IOED. Another metacognitive heuristic, retrieval fluency, produces overconfidence when information feels easy to process. Across several domains participants were more confident when something feels more fluent (Alter & Oppenheimer, 2009). The availability heuristic influences decision making based on how easy it is to bring something to mind. Quickly remembered examples and more readily available examples are perceived as being more likely or true. Dodson, Garrett, Kafadar and Yaffe (2021) found the more quickly a witness makes an identification on a line up, the more accurate participants perceived them to be. The present study will record how long participants take to make decisions, given the use of heuristics would imply quicker decision time. Perhaps the IOED difference found in Rozenberg (2021) study may be a result of utilising different processes; intuition (heuristics) vs deliberation, when considering their individual knowledge and shared knowledge respectively.

Purpose of linking the IOED and TMS literature

Two seemingly distinct areas of research have been discussed. First the IOED and its presentation in individuals. Secondly, transactive memory systems and it's development within small groups, specifically those in close relationships. Both fields of literature identify scope for further research, this study will examine a potential connection between these two fields, providing a deeper understanding to the mechanisms of each. The aim of the current study is twofold, one to replicate Rozenberg's (2021) exploratory results. This will be

achieved by exploring how collaborating within a transactive memory system effect the IOED, by examining self, partner, and dyad ratings of knowledge in collaborative and nominal groups. Second, to conduct exploratory research looking at possible mechanisms underlying her findings. This will be continued by the inclusion of participant confidence ratings in their decision making and timing their decisions. Through examining their decision-making processes, the present study will explore possible differences between an individual's ability to assess their own knowledge versus shared knowledge. There are practical applications of this research in several fields mentioned earlier, such as eyewitness accounts, aviation, and medical fields. In these and many other fields, having a robust understanding of how individuals assess their own knowledge in contrast to the knowledge they have access to, is essential.

Hypotheses

Four primary hypotheses are as follows, first, as the IOED literature base predicts, it is hypothesised post-task self-ratings of knowledge will be lower than pre-task self-ratings. Informed by Rozenberg's (2021) findings, it is hypothesised an IOED will not be demonstrated for knowledge ratings of partners or dyads. That is there will be no change in post-task ratings compared to pre-task ratings in partner and dyad knowledge ratings. This would support the suggestion the IOED arises because people are mistaking what they can recall alone for what they recall in a socially supported environment. Therefore, it is predicted when estimating the knowledge of their TMS, their socially supported knowledge environment, there will be no "illusion" and thus show no change in knowledge ratings. Should the results show post-task ratings of knowledge lower than pre-task ratings, it would suggest people are equally poor at estimating the knowledge of their TMS and accessing socially distributed knowledge may not be the solution to overcoming the IOED.

Thirdly it is expected participants will rate have higher confidence ratings for their own knowledge ratings than those of their partner and dyad. This hypothesis is predicted by retrieval fluency, that given it will be easier to recall their own knowledge, it is likely participants will have greater confidence in their own knowledge.

Lastly, it is expected self-ratings will be faster than ratings made about their partner or the dyad. If as Keil (2012) suggests, and people are using heuristics to examine explanatory knowledge, the results would show self-ratings as faster than ratings made about the partner and dyad.

Research questions

Given the exploratory nature of the present study, research questions were included and are as follows.

- Will there be a difference in task performance between collaborative and nominal groups?

If the results show collaborative groups make fewer errors, this would be consistent with collaborative facilitation and that there are memory benefits to collaborating. Should collaborative groups make fewer errors, this would support collaborative inhibition research and have implications for TMS. Given there is literature and theory to support both collaborative facilitation and inhibition, this has been posed as a research question.

The following research questions aim to explore how “accurate” participants are when estimating their knowledge.

- Will self pre-ratings predict nominal or collaborative group performance?
- Will dyad pre-ratings predict nominal or collaborative group performance?
- Will nominal group performance predict self or dyad post-ratings?
- Will collaborative group performance predict self or dyad post-ratings?

This will be examined through correlating knowledge ratings with error rates and aims to explore the theory that the IOED is a result of people misinterpreting what they achieve alone for what they can achieve with access to a web of knowledge. If dyad knowledge ratings are more highly correlated with performance, this may support this theory. If self knowledge ratings are more highly correlated with performance, it may be people are not mistaking what they can achieve alone for what they can achieve with access to a supported social environment.

Method

Participants

88 participants were recruited, data of 76 participants (38 pairs) were included in the analysis. Data excluded from the analysis were for one of the following reasons: participants either not completing the drawing task, the software not saving the data or being the partner of a participant, whose data was not able to be included.

Participants were recruited through several channels: Massey University distance undergraduate psychology courses, Massey University Psychology Facebook pages and the researcher's personal social media. It was made clear in the poster used, that participants were required to sign up in pairs and register interest by emailing in together. Those who emailed in without a partner were encouraged to find a partner to participate with. Of all those who registered interest, all were required to be a.) 18 years of age or over b.) have an ability to speak and understand written English c.) have access to a laptop or desktop computer.

Pairs of participants were presumed to have established a transactive memory system, as the researcher assumed participants would sign up with a partner whom they knew reasonably well. As such, length of relationship was collected, 2 participants knew each other less than 6 months (2 nominal participants), 2 between 7-12 months (2 nominal participants), 7 between 1-2 years (3 nominal, 4 collaborative) and 65 participants knew each other 2+ years (31 nominal, 34 collaborative). One pair disagreed on the length of relationship, one reported 1-2 years, the other 2+ years. Given the similarity of the answer, this pair was still included in analysis.

Participants were asked to self-report gender identity through an explanation box, 35 reported to identify as male, 40 as female and 1 as non-binary. Participants were also asked to self-report ethnicity through an explanation box, of these 54 identified as NZ European, Pākehā, or European (Italian, Irish, Scottish and European), 10 as Asian (Chinese, Korean, Filipino, and Asian), 5 as Indian, 3 as Māori, 1 as Latina, 1 as Australian, 1 as Fijian and 1 declined to report.

The age of participants ranged from 17 to 71 years, with a mean age of 35 years, a median age of 29 years. (Collaborative group: mean=28 years, median=26 years, Nominal group: mean=42 years, median=39 years). One participant aged 17yrs was included, as they soon turned 18.

Table 1*Participant familiarity with bicycles*

Familiarity with bikes		
	Yes	No
Can you ride a bike?	73 (37 nominal, 36 collaborative)	3 (1 nominal, 2 collaborative)
Do you own a bike?	44 (25 nominal, 19 collaborative)	32 (13 nominal, 19 collaborative)
Have you repaired a bike?	39 (17 nominal, 22 collaborative)	37 (21 nominal, 16 collaborative)

Materials

The software used in the present study was previously designed for Rozenberg's (2020) study in response to restrictions enforced due to the Covid-19 outbreak in New Zealand during 2020. The present study followed an online format, to ensure should there be additional Covid-19 related restrictions in 2021, the study could continue. The software was adapted for the present study, these changes included but were not limited to, having two versions of the study: one for each nominal and collaborative group, including a timing function and removing a previous chat function. The software was designed to follow a similar experimental paradigm as (Lawson, 2006) while expanding upon it to investigate the IOED in TMS. Participants were first asked to rate their knowledge of bicycles (pre-task ratings), then complete a schematic drawing of a bicycle, complete three multichoice questions concerning a bicycle's structure and lastly rerate their knowledge of a bicycle (post-task ratings). These sections of the task will be discussed in more detail, while highlighting the modifications made for this study.

Pre-task

Participants were asked to rate their knowledge of bicycles on a Likert scale from 1 (I know little or nothing about how bikes work) to 10 (I have a thorough knowledge of how bikes work). These questions were a replication of Lawson's (2006) although Lawson used a 7-point Likert scale. The present study included two additional questions asking participants to rate their partners knowledge and their combined knowledge (as a pair) of bicycles on the

same 10-point Likert scale. These questions were included to investigate IOED's in TMS, which Lawson (2006) did not.

Two additions were made to this first stage to look at possible mechanisms by which the IOED may be different in TMS's, these were inclusion of confidence ratings and timing of decision making. Confidence rating questions followed each knowledge rating question. Participants were asked how confident they were of the previous knowledge rating on a 10-point Likert scale from 1 (I have no confidence) to 10 (I'm highly confident). As participants in the collaborative group completed the survey together, they were instructed to nominate a Person A and Person B within the pair. First person A was asked to make the knowledge ratings and corresponding confidence ratings, following which Person B then answered the same knowledge and confidence rating questions. In the nominal group individuals within the pair completed the survey separately, they were asked the same questions as the collaborative group, while additional instructions were given at the beginning of the survey acknowledging they weren't together, however asking they gave their "best guess".

Participants were timed how long they spent on a page that included a Likert scale question (knowledge and confidence ratings) by recording the time from the page appeared to the time the participant clicked "Next". This was used as a measure for investigating how long participants took to make decisions and labelled, Speed of knowledge rating and Speed of confidence rating.

Tasks

Participants next completed two tasks, used to assess their knowledge of bicycles. In the first task participants were required to complete a simple schematic drawing of a bicycle, in which the two wheels were already drawn for them. Instructions explained to participants the aim was to represent a bicycle as accurately as possible and it didn't need to be artistic. Simple pictures representing parts of the bicycle required to be part of the drawing were depicted to the right of the sketch pad, along with instructions to include these in the drawing. There was both a pen function and eraser, which they could use with a mouse or touch pad. There was no time limit for participants to complete the drawing within. (Snapshot of bike task screen).

The second task included 3 forced choice questions, in each question participants were asked to choose 1 of 4 schematic drawings of a bicycle that best represent the position of the frame, pedals and chain. This followed the structure of Lawson's (2006) study, and the pictures were a direct copy of her study. As shown in Figure xx below.

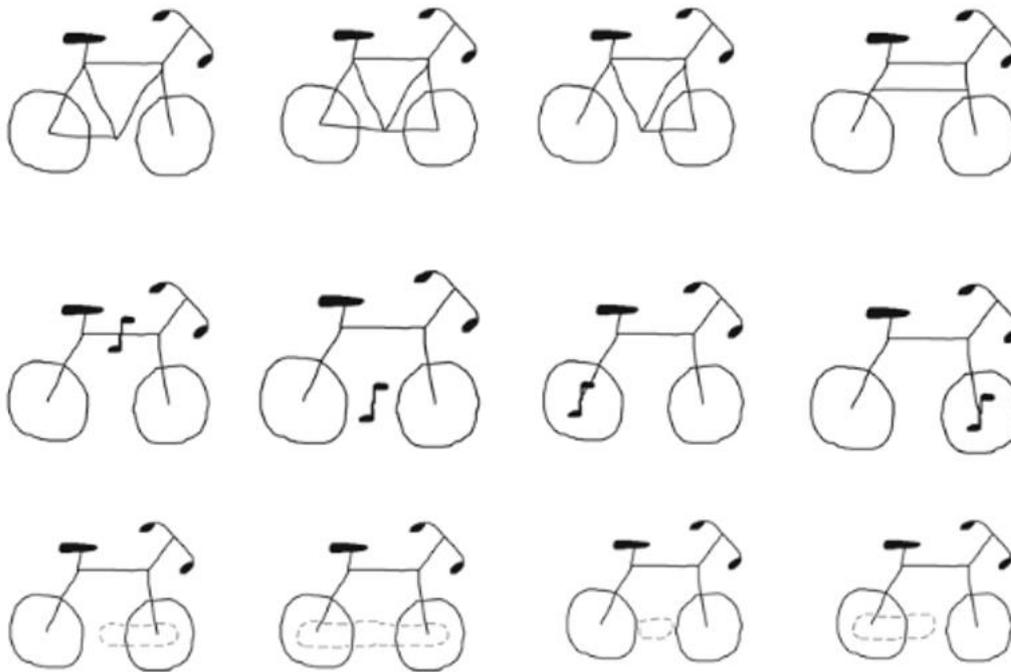


Figure 2. Three forced choice tasks in which participants were required to select the most accurate drawing representing a bike frame, pedals and chain.

Participants in the collaborative group completed the tasks together as a pair, whereas participants in the nominal group completed the tasks alone as they independently accessed the survey.

Post- task

Following the tasks, participants were asked the same knowledge and confidence rating questions, following the same format of those they had answered prior to the task.

Procedure

Participants were reached in a variety of ways as mentioned above, those who met the criteria to participate in the study were encouraged to email the researcher. Those who emailed registering interest were provided with an information sheet about the study, along with an explanation regarding which group they were randomly allocated into. This email also included the link to either the collaborative or nominal variation of the survey, along with a description that they may access the survey at any time, should they decide to take part. In pre-registration it was anticipated participants may need to book a time slot, as the software

only allowed for one pair to use it at a time. The changes made to the software from the previous year allowed for multiple participants to use it at a time, meaning participants were no longer required to book at time slot. This meant participants completed the survey on their own laptops or desktop computers. Participants were instructed that the survey must be completed on a laptop or desktop computer and that it couldn't be completed on a tablet or phone.

Pairs of participants were randomly allocated into either the collaborative or nominal group, using a flip a coin webpage, until one group met the required number of participants and rest were allocated to the other group. There were two versions of the software, one for the collaborative group to complete the survey together sharing a computer and another designed for the nominal group in which pairs of participants completed the survey independently and were instructed not to speak to their partners about the survey. Participants indicated consent to participate through ticking a box at the beginning of the online survey, they were only able to continue to the next page in the survey if they had indicated consent. Completion of the survey required participants to answer all questions, complete the tasks and answer follow up questions. The survey in its entirety took approximately 15 minutes to complete.

Data of participants who did not appropriately complete the survey was excluded from analysis (12 participants). Reasons qualifying exclusion were, those who drew pictures unrelated to the task, those who didn't complete the survey or being the partner of a participant, whose data was excluded.

Results

Scoring, Variables and treating of the data

The two bike tasks were scored by compiling errors following Lawson's (2006) scoring process and as set out in the pre-registration. These are described as below:

Free Drawing Task

There are three types of errors in the free drawing task which would severely impact the functioning of the bicycle. These are classified as: frame, pedal and chain errors, and are described below.

- Frame errors: include joining the front and back wheels and making the bicycle impossible to steer.

- Pedal errors: include failing to draw the pedals between the two-wheels and within the chain, making the chain unnecessary or the pedals difficult to reach (such as if attached to the front or back wheels).
- Chain errors: include failing to draw the chain around the pedals and the back wheel only, such as drawing the chain looped around both wheels, making the bicycle becomes impossible to steer unless the chain can stretch.

Participants can make a maximum of three errors, one in each section. In the free drawing task, all scores for this section range from 0 to 3 inclusive. Errors in this section will be counted manually.

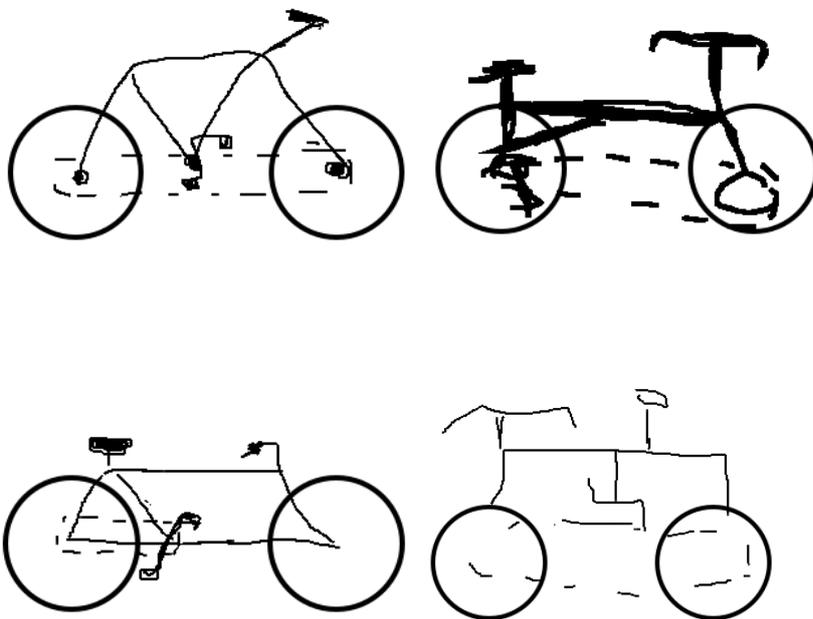


Figure 3. Examples of drawings with errors.

Forced Choice Task

In the forced-choice task, the correct answers were as follows: the first image for the frame; the second for the pedals; and the fourth for the chain. All other responses in these questions were counted as errors. Participants could score a maximum of three errors, one per question in this section. In the pre-registration it was proposed drawing and forced choice error scores would be combined to give a total error score (maximum score of 6) such as Lawson (2006) did. It was decided later that free drawing task errors and forced choice task

errors would also be examined separately. To better understand the possible relationship between errors and knowledge ratings.

As described in the method section, there were two versions of the survey for either Group. One which was designed for dyads to complete together (collaborative group), the other designed for the two individuals of the dyad to complete separately (nominal group). Knowledge ratings in both the collaborative and nominal groups were made by individuals. Data collected from collaborative dyads included two individuals' ratings and one group error rate, whereas data collected from nominal dyads included individual ratings and an individual error rate.

The present study was interested in how dyads performed on the task and how collaboration impacted this performance. To compare the nominal dyad performance, errors of the nominal dyads were combined. If either individual in the nominal pair made an error, it was counted once; if both made the same error it was only counted once. Collaborative pairs did the task together and so had one score between them. This means of comparing the performance of collaborating and non-collaborating pairs was borrowed from the method used in the collaborative recall literature (Browning, Harris, Van Bergen, Barnier & Rendell, 2018).

Measured variables

Knowledge and confidence ratings were scored on a 10-point scale, pre and post task. These were made about three Targets, the self, partner, and dyad. All knowledge ratings were made by individuals, in both the collaborative and nominal versions of the survey and therefore were treated as such in all repeated measure ANOVAs. The Speed at which all knowledge and confidence ratings were made was measured (in seconds). All ratings were made by individuals, in both the collaborative and nominal versions of the survey and therefore Speed of ratings data, were treated as such in all repeated measure ANOVAs.

Table 2.

Knowledge rating mean scores for self, partner and dyad made by individuals (standard deviations depicted in brackets) pre and post task.

	Self	Partner	Dyad
Pre task	6.64 (2.24)	6.60 (2.33)	7.54 (1.75)
Post task	7.04 (1.71)	6.92 (2.34)	7.85 (1.58)

As Table 2 demonstrates, knowledge ratings increased from pre- to post-task for all targets (self, partner, and dyad).

Pre-registered analyses

All analyses were carried out using Jamovi (version 1.6.23). The first hypothesis predicted evidence of an IOED in self-knowledge ratings; that is, the post-task ratings of knowledge made about the self would be lower than pre-task ratings made about the self, following completion of the knowledge task. A 2x2x3 repeated measures ANOVA was used to look at the impact of Group (collaborative and nominal) over Time (pre- and post-task) on knowledge ratings, made about Targets (self, partner, dyad). The assumption of sphericity was shown to be violated by the Mauchly's test, consequently the Greenhouse-Geisser adjustment was used. The Levene's test showed that the data violated homogeneity of variance, although it is worth noting the difference between the biggest and smallest standard deviations was moderate for a 10-point scale. Nonetheless these findings should be interpreted with caution, especially for those near .05. In none of the cases did the findings provide 'near hits' for the hypothesis.

A main effect was found for Time; however it showed a statistically significant *increase* from pre- to post-task knowledge ratings, $F(1,78)=6.022$, $p=0.016$, partial $\eta^2=0.072$, instead of the predicted decrease in knowledge ratings made about the self. The significant increase found from pre task ($M=6.64$, $SD=2.24$) to post task ($M=7.04$, $SD=1.71$) meant the first hypothesis was not supported.

The second hypothesis predicted no evidence of an IOED would be found in knowledge ratings made about partners and the dyad, that is there would be no change from pre- to post-task in knowledge ratings of partner and dyad. This was not supported by the same repeated measures ANOVA, as no significant interaction was found between Target (self, partner, dyad) over Time (pre and post). That is, there was no difference in who the knowledge

ratings were made about (self, partner, or dyad), all knowledge ratings increased consistently over time. However a statistically significant main effect was shown for Target (self, partner, dyad) ratings, $F(1.39, 108.78)=8.46, p=0.002, \text{partial } \eta^2= 0.098$. That is, individuals rated dyad knowledge ($M=7.69, SD=1.67$) as significantly greater than self ($M=6.84, SD=2.00$) or partner ($M=6.76, SD=2.33$) knowledge as can be seen in Table 2. This may indicate participants hold a belief that “two heads are better than one”, that together they know more about bicycles.

This same factorial repeated measures ANOVA also showed a significant interaction effect between Time (pre and post), Target (self, partner, dyad) and Group (collaborative, nominal) $F(1.74, 139.18)=3.80, p<0.001, \text{partial } \eta^2= 0.096$. That is, it appears knowledge ratings (of self, partner, and dyad) change differently from pre to post, in collaborative and nominal groups. From examining Figure 4. below, the interaction effect appears to be driven by differences in ways the nominal and collaborative groups made their self and partner knowledge ratings. Self-knowledge ratings in the nominal group increased noticeably more from pre- to post-task than in the collaborative group, where self-ratings in the collaborative group appeared relatively consistent. By contrast, partner knowledge ratings increased more from pre to post in the collaborative group than was the case for nominal groups.

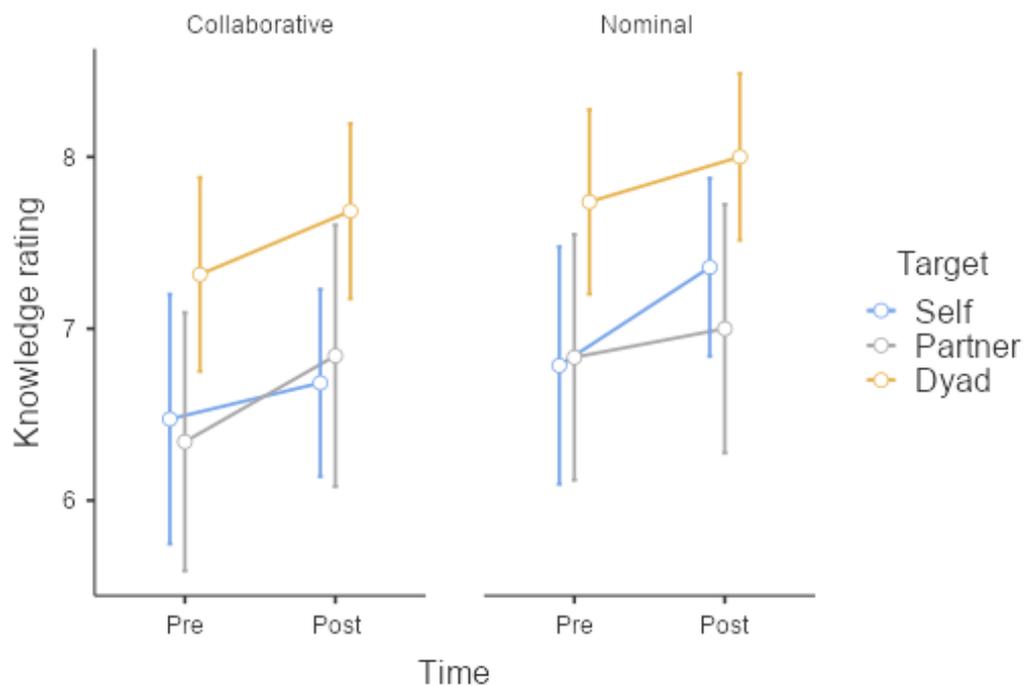


Figure 4. Mean knowledge ratings from pre- to post-task, in collaborative and nominal group. Vertical lines show $\pm 95\%$ confidence intervals (lower and upper).

The third hypothesis predicted higher confidence ratings of self- than of partner- and dyad- knowledge ratings. The results of a $2 \times 3 \times 3$ factorial repeated measures ANOVA were used to examine the effect of Group (collaborative and nominal) over Time (pre and post) on confidence ratings made about the judgements of knowledge for the three Targets (self, partner, dyad). The assumption of sphericity was shown to be violated by the Mauchly's test, consequently the Greenhouse-Geisser adjustment was used. The Levene's test showed that the data violated homogeneity of variance, although it is worth noting the difference between the biggest and smallest standard deviations was moderate for a 10-point scale. Nonetheless these findings should be interpreted with caution, especially for those near .05. In none of the cases did the findings provide 'near hits' for the hypothesis.

A statistically significant main effect for Target $F(1.78, 139.18)=8.329, p<0.001$, partial $\eta^2=0.096$, was found whereby individual confidence ratings for self ($M=8.12, SD=1.58$) and dyad ($M=8.14, SD=1.48$) knowledge ratings were equally high, in contrast to a lower confidence in partner ($M=7.62, SD=1.81$) knowledge ratings. As a result, the third hypothesis was not supported.

This effect appears to be largely contributed to by the significant interaction effect between Target and Group $F(1.78, 139.18)=4.425, p=0.017, \text{partial } \eta^2= 0.054$. This is depicted in Figure 5. in which confidence ratings made by those in the nominal group, about partners ($M=7.18, SD=1.86$) are significantly lower than self ($M=8.09, SD=1.52$) and dyad ($M=8.08, SD=1.61$) ratings. In contrast, confidence ratings made by those in the collaborative group about self ($M=8.01, SD=1.66$), partner's ($M=7.92, SD=1.70$) and dyad ($M=8.11, SD=1.37$), appears less varied as can be demonstrated in Figure 5.

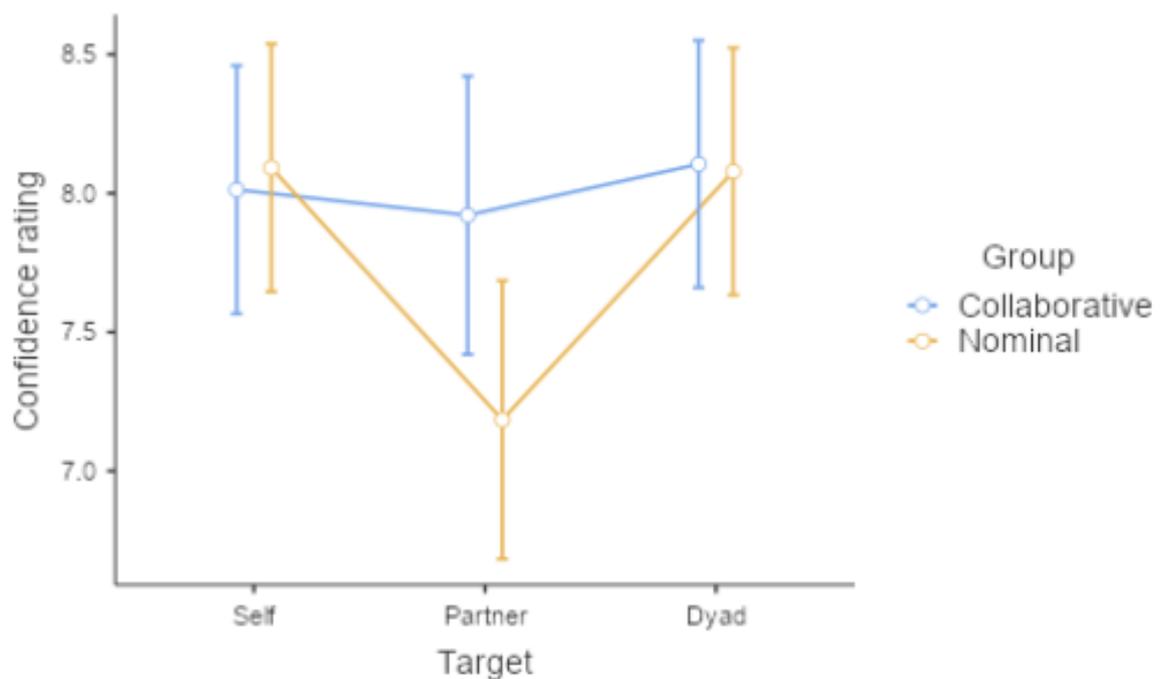


Figure 5. Mean (average across pre- and post-task) confidence ratings of self, partner, and dyad knowledge ratings in both collaborative and nominal groups. Vertical lines show $\pm 95\%$ confidence intervals (lower and upper).

The analysis also indicated confidence ratings increased over Time $F(1, 78)=16.759, p<0.001, \text{partial } \eta^2= 0.177$. That is confidence ratings pre-task ($M=7.73, SD=1.78$) were lower than confidence ratings post-task ($M=8.18, SD=1.46$). This appears to be largely because of an increase in confidence ratings from pre- to post-task in the collaborative group. A significant interaction between Time and Group $F(1,78)=11.102, p=0.001, \text{partial } \eta^2= 0.125$, can be seen in Figure 6. Confidence ratings made by those in the collaborative group increased significantly from pre- ($M=7.59, SD=1.81$) to post- ($M=8.44, SD=1.17$) task, whereas confidence ratings made by those in the nominal group appear to have remained reasonably consistent from pre- ($M=7.74, SD=1.78$) to post- ($M=7.83, SD=1.66$) task.

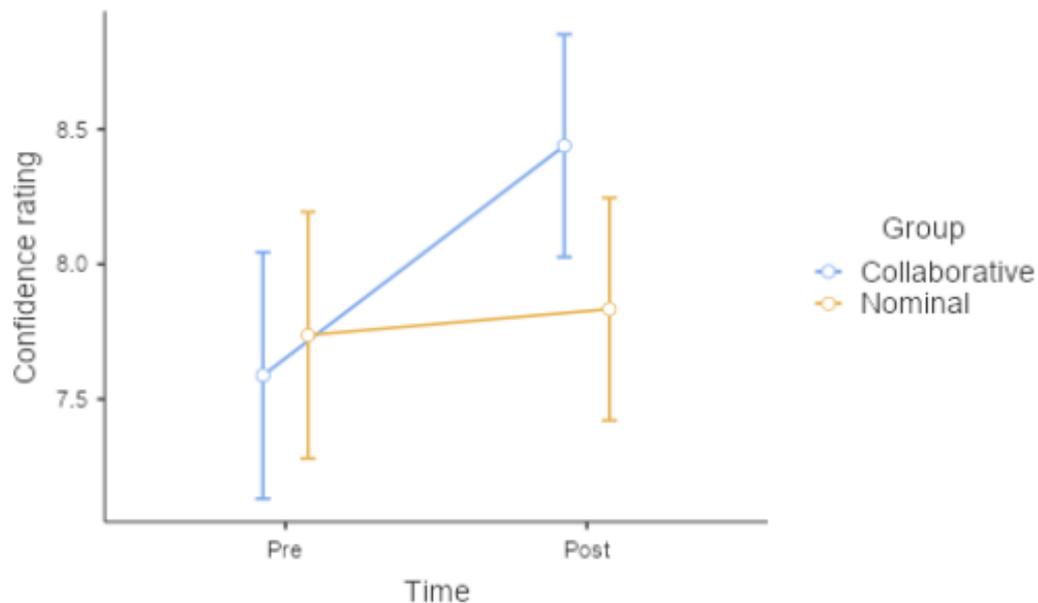


Figure 6. Mean confidence ratings from pre to post task in both collaborative and nominal groups. Vertical lines show \pm 95% confidence intervals (lower and upper).

The fourth hypothesis predicted individuals' ratings about their self will be faster than their ratings made about their partner and the dyad. It was predicted this would be the case for both confidence and knowledge ratings. Speed of knowledge ratings will be discussed first, followed by speed of confidence ratings.

Speed of knowledge ratings

The hypothesis was not supported by a 2x2x3 repeated measures factorial ANOVA, measuring the impact of Group (collaborative and nominal) over Time (pre and post task) on Speed of knowledge ratings made about Targets (self, partner, dyad). The assumption of sphericity was shown to be violated by the Mauchly's test, consequently the Greenhouse-Geisser adjustment was used. The Levene's test showed that the data violated homogeneity of variance, thus these findings should be interpreted with caution, especially for those near .05. In none of the cases did the findings provide 'near hits' for the hypothesis.

A significant main effect for Speed of knowledge ratings was found $F(1.58, 123.55) = 22.437$, $p < 0.001$, partial $\eta^2 = 0.223$, in which ratings made about self ($M = 18576$, $SD = 11564$), were found to be significantly *slower* than knowledge ratings made about the partner ($M = 12093$, $SD = 16401$) or dyad ($M = 12420$, $SD = 12284$). It is possible this was contributed to by an order effect, as self-ratings were the first ratings made by participants. This may be supported by

the evidence of a significant main effect for Time $F(1,78)=26.591, p<0.001$, partial $\eta^2=0.254$, in which pre-task ratings ($M=18150, SD=16647$) were significantly slower than post-task ($M=10576, SD=8956$) ratings. Figure 7. depicts a non-significant interaction between Time and Target for Speed of knowledge ratings. Post-task ratings of self were of a similar speed to pre-task ratings of partner and dyad. Speed of confidence ratings discussed in following paragraphs shows a significant interaction between Time*Target.

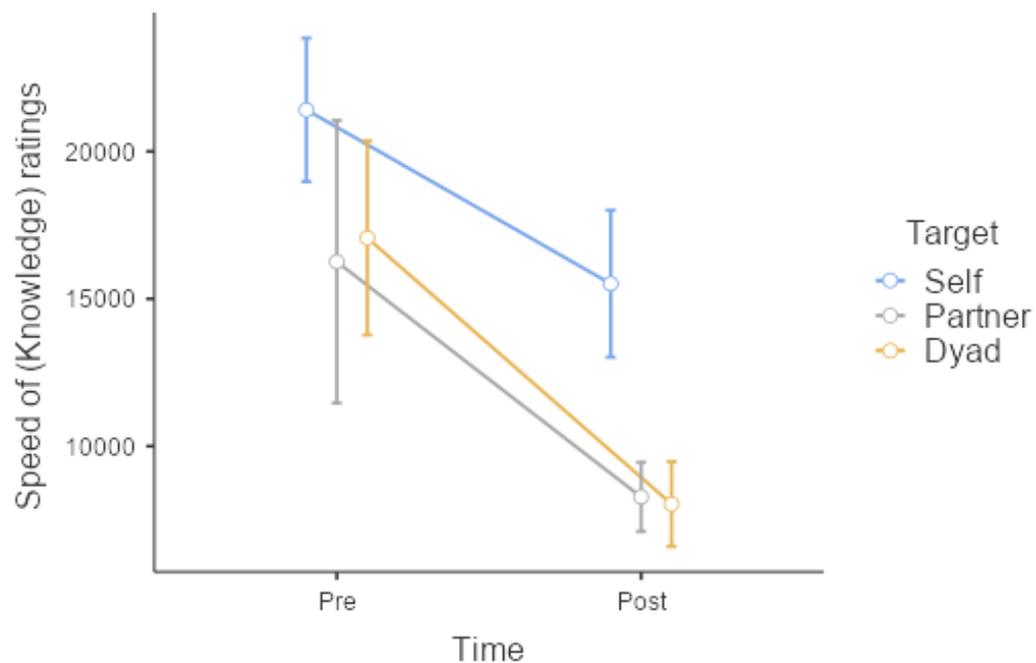


Figure 7. Mean speed of knowledge ratings made about the self, partner, and dyad, from pre to post task. Vertical lines show $\pm 95\%$ confidence intervals (lower and upper).

Speed of confidence ratings

A 2x2x3 repeated measures factorial ANOVA was used to examine the impact of Group (collaborative and nominal) over Time (pre and post task) on Speed of confidence ratings made about Targets (self, partner, and dyad). The assumption of sphericity was shown to be violated by the Mauchly's test, consequently the Greenhouse-Geisser adjustment was used. The Levene's test showed that the data violated homogeneity of variance, thus these findings should be interpreted with caution, especially for those near .05. In none of the cases did the findings provide 'near hits' for the hypothesis.

A significant main effect for Target was found $F(1.38,107.33)=62.870$, $p<0.001$, partial $\eta^2=0.446$, in which confidence ratings made about the self ($M=8610$, $SD=6235$), were significantly slower than those made about the partner ($M=5050$, $SD=2822$) or dyad ($M=4765$, $SD=2703$), also not supporting the fourth hypothesis. This also may be contributed to by an order effect, as a significant main effect for Time was found $F(1,78)=103.286$, $p<0.001$, partial $\eta^2=0.570$, in which pre-task ratings ($M=7641$, $SD=5270$) were significantly slower than post-task ratings ($M=4642$, $SD=3143$). Time and Target of Speed of confidence ratings showed a similar pattern of interaction as mentioned in Speed of knowledge ratings. However a significant interaction was found $F(1.57,122.70)=30.322$, $p<0.001$, partial $\eta^2=0.280$. As shown by Figure 8, there was a far greater change in self ratings from pre to post than in self and partner ratings. Similar to Speed of knowledge ratings, Speed of confidence ratings of self, post-task was approximate to speed of dyad and partner ratings pre-task.

A significant main effect for Group was found $F(1,74)=12.7$, $p<0.001$, partial $\eta^2=0.147$, in which the collaborative group took significantly longer ($M=7116$, $SD=4911$) than the nominal group ($M=5167$, $SD=4017$) to make decisions about confidence ratings. No such Group effect was observed for Speed of knowledge ratings. When comparing Speed of knowledge ratings and Speed of confidence ratings, it appears participants took considerably longer to make decisions about knowledge ratings than confidence ratings.

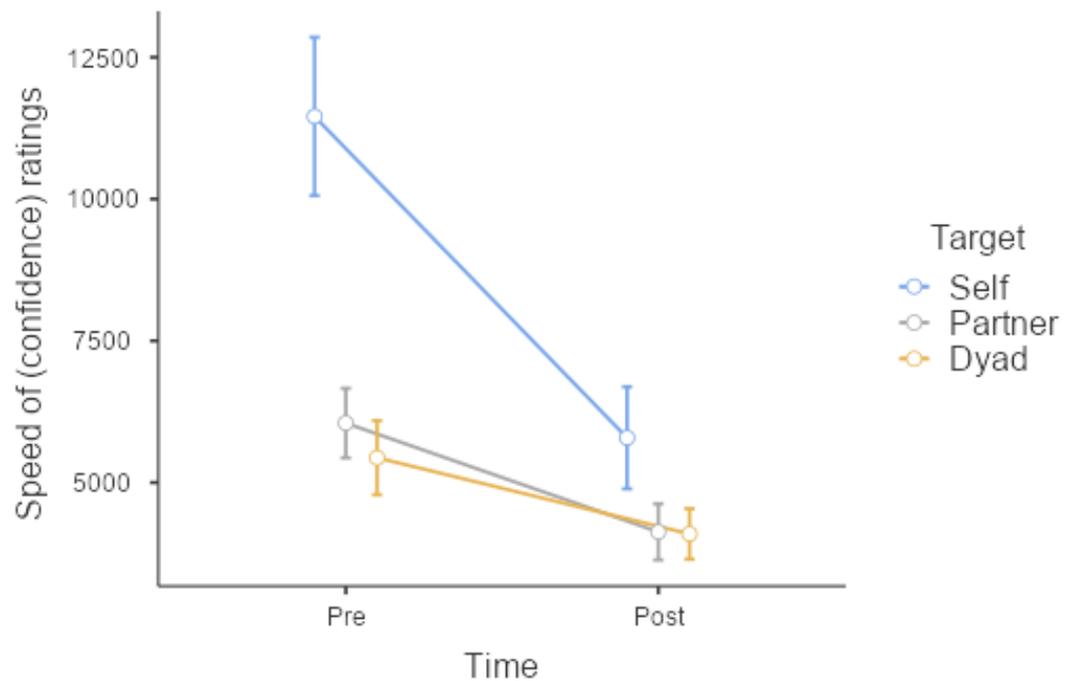


Figure 8. Mean speed of confidence ratings made about the self, partner, and dyad, from pre to post task. Vertical lines show \pm 95% confidence intervals (lower and upper).

Exploratory analysis

Task performance

The first pre-registered research question asked, “Will there be a difference in task performance between collaborative and nominal groups?”. As previously described, task performance was scored by errors in the two tasks. As depicted in Table 2 there is a considerable difference in errors made by collaborative and nominal dyads. 15.8% of those in the collaborative group made two or more total errors, whereas 73.7% of those in the nominal group made two or more total errors. When comparing the drawing errors and forced choice errors, both groups made fewer errors in the forced choice task than the drawing task. 36.8% of nominal dyads made one or zero drawing errors, whereas 89.5% of collaborative dyads made one or zero drawing errors.

Table 3.

Percentages of total errors made, broken down into drawing and forced choice errors made by nominal and collaborative dyads.

Error type	Number of errors	Group type	
		Nominal	Collaborative
Total errors	0	10.5%	21.1%
	1	15.8%	63.2%
	2	26.3%	10.5%
	3	10.5%	5.3%
	4	15.8%	-
	5	5.3%	-
	6	15.8%	-
Drawing errors	0	10.5%	21.1%
	1	26.3%	68.4%
	2	42.1%	10.5%
	3	21.1%	-
Forced choice errors	0	42.1%	89.5%
	1	21.1%	10.5%
	2	21.1%	-
	3	15.8%	-

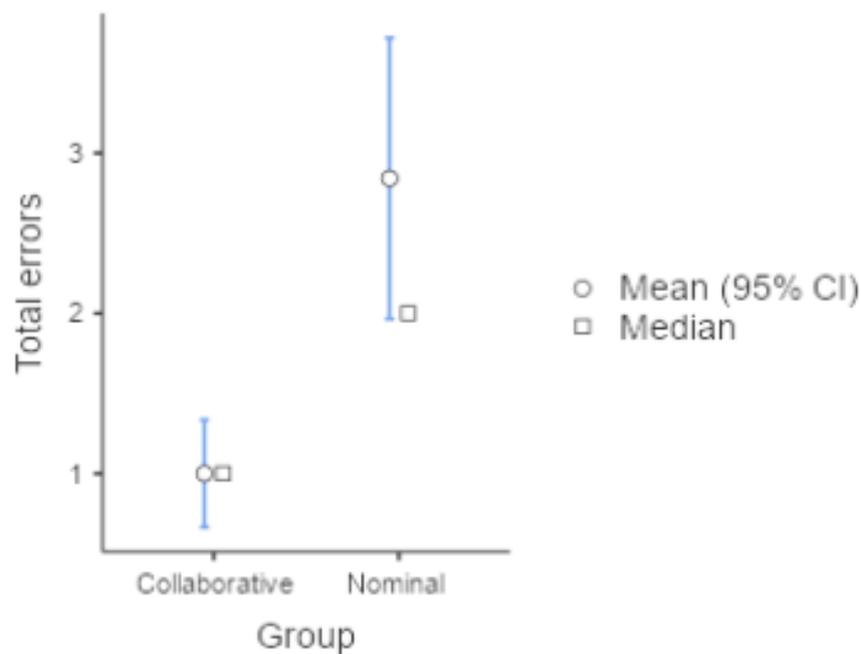


Figure 9. Mean and median of total errors made by collaborative and nominal dyads. Vertical lines represent 95% confidence intervals.

As seen in Figure 9, it was beneficial to complete the task collaboratively. Levene's test was significant suggesting a violation of the assumption of equal variances, thus a Welch's t-test was carried out, $t(23)=-3.84$, $p<0.001$, collaborative groups made a mean total error of 1 ($SD=0.745$) whereas nominal groups made a mean error of 2.842 ($SD=1.951$).

It also is important to note there may not be the necessary sample size to ensure sufficient power for these analyses.

Relationship between knowledge ratings and performance

Further pre-registered research questions were concerned with participants ability to "predict" their performance on the tasks. They are listed below:

- Will individual pre-ratings predict nominal or collaborative group performance?
- Will dyad pre-ratings predict nominal or collaborative group performance?
- Will nominal group performance predict individual or group post-ratings?
- Will collaborative group performance predict individual or group post-ratings?

It is important to note in the following analyses, there may not be the necessary sample size to ensure sufficient power. The following Table 4 and Table 5 depict the correlation matrices of errors made with knowledge ratings, in the nominal group (Table 4) and collaborative group (Table 5). Each research question will be discussed below:

Will individual pre-ratings predict nominal or collaborative group performance?

The results of a Pearson's correlation showed no significant relationship between self pre-task ratings with total errors, drawing errors or forced choice errors in either the nominal or collaborative group.

Will dyad pre-ratings predict nominal or collaborative group performance?

The results of a Pearson's correlation showed dyad pre-task ratings had a nonsignificant correlation of $r=0.427$, $p=0.075$ with total errors in the nominal group. Dyad pre-task ratings also had a significant correlation of $r=0.457$, $p=0.037$ with total drawing errors in the nominal group. These results suggest perhaps participants in the nominal group had some understanding of the knowledge that was held within their dyad. The results of a Pearson's correlation showed little to no relationship between dyad pre-task ratings and total, drawing or forced choice errors, in the collaborative group.

Will nominal group performance predict individual or group post-ratings?

The results of a Pearson's correlation showed little to no relationship between total, drawing or forced choice errors and self post-task ratings in the nominal group.

The results of a Pearson's correlation showed dyad post-task ratings had a nonsignificant correlation of $r=-0.386$, $p=0.084$ with total errors, a correlation of $r=-0.366$, $p=0.103$ with total drawing errors and a correlation of $r=-0.386$, $p=0.110$ with total forced choice errors.

Will collaborative group performance predict individual or group post-ratings?

The results showed no relationship between errors and either self or dyad post-task ratings in the collaborative group.

Table 4.

Nominal group correlation matrix for total errors, (also broken down into total drawing errors, total forced choice errors), and knowledge ratings made about the self, partner and dyad, pre and post task.

	Total errors	Total drawing errors	Total forced choice errors	Self Pre	Dyad Pre	Self Post	Dyad Post
Total errors	—						
Total drawing errors	0.922 ***	—					
Total forced choice errors	0.949 ***	0.752 ***	—				
Self pre	0.167 ⁻	-0.306	0.028 ⁻	—			
Dyad Pre	0.427 ⁻	0.457* ⁻	0.351 ⁻	0.682 **	—		
Self Post	0.179 ⁻	-0.284	0.067 ⁻	0.519 *	0.380	—	
Dyad Post	0.386 ⁻	-0.366	0.359 ⁻	0.333	0.639 ***	0.748 **	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 5.

Collaborative group correlation matrix for total errors, (also broken down into total drawing errors, total forced choice errors), and knowledge ratings made about the self, partner and dyad, pre and post task.

	Total errors	Total drawing errors	Total forced choice errors	Self Pre	Dyad Pre	Self Post	Dyad Post
Total errors	—						
Total drawing errors	0.920 ***	—					
Total forced choice errors	0.709 ***	0.376	—				
Self Pre	0.117	0.227	-0.131	—			
Dyad Pre	0.085	0.122	-0.018	0.660 **	—		
Self Post	0.107	0.082	0.107	0.703 ***	0.461 *	—	
Dyad Post	0.081	-0.081	-0.047	0.391	0.680 **	0.662 **	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 6.

Reasons participants gave for changing their post-task knowledge rating.

Possible reasons for changing score	Participants
It didn't change	31 (15 nominal, 15 collaborative)
Couldn't recall the details of a bike	21 (10 nominal, 11 collaborative)
Never understand how a bike worked	8 (3 nominal, 5 collaborative)
Other	20 (10 nominal, 7 collaborative)

Reasons given under “Other” appeared to be explanation for the score increasing, eg. The task was simple, the task increased my confidence, thought the task would require more detail than it did.

Discussion

The present study aimed to explore how collaboration within a transactive memory system, may affect the expression of the illusion of explanatory depth. It was designed in response to theoretical predictions the IOED may be, in part, caused by individuals being unknowingly reliant on socially distributed knowledge. This explanation for the IOED, as well as suggested in the TMS literature, implied there are benefits to collectively held knowledge. Thus, the present study aimed to contribute to both the IOED and TMS literature, by furthering the understanding of how it is individuals assess their knowledge, both individual and shared. Alongside examining the IOED in individuals and small groups, the study also assessed the effects of collaboration on the task.

Previous research by Rozenberg (2021) first explored how the IOED may be influenced by individuals accessing a TMS. Rozenberg (2021) found that when individuals made knowledge ratings about themselves, they showed an IOED, however knowledge ratings about their partner and dyad didn't. This result gave a rationale for further exploring the IOED in TMS – firstly to replicate her findings, and secondly to explore the different possible mechanisms behind Rozenberg's (2021) findings. One hypothesis proposed for Rozenberg's (2021) findings was when contemplating others knowledge, individuals may utilize different decision-making processes when thinking about different 'knowledge targets', thus avoiding the IOED for judgements of the knowledge of partners and dyads. An alternative hypothesis was people may be better calibrated to thinking as a team and so the knowledge ratings given for a dyad are more 'accurate' thus a change from pre- to post-task for dyad judgements is not observed. Consequently, the purpose of the present study was to replicate and expand upon Rozenberg's (2021) findings. A between-subjects design was implemented to reduce learning across conditions. The introduction of confidence ratings and speed of judgements was to better understand the mechanism by which different results were found.

Surprisingly, given the comprehensive literature base, the results of the present study did not demonstrate the characteristic IOED; that is, a drop in knowledge ratings from pre- to post-task. Instead, knowledge ratings increased from pre- to post-task for all participants,

across Groups and Targets. The results and following implications for both IOED and TMS literature will be discussed further in the following section.

Hypotheses

Unexpectedly the first hypothesis, which predicted post-task self-knowledge ratings would be lower than pre-task self-knowledge ratings was not supported. Instead, an increase in ratings from pre- to post-task was observed. This is contrary to the majority of literature regarding the IOED, including Rozenberg's (2021), Lawson's (2006) and Rozenblit and Keil's (2002) findings which the present study is founded on. Their studies all found a decrease in knowledge ratings following completion of an explanatory knowledge task, albeit Lawson's (2006) study did not find a significant decrease. It is suggested in the IOED literature, that only when participants are required to operationalise their knowledge and are confronted by the difficulty or their inability to do so, do they realise the limits of their knowledge. Consequently, producing the characteristic reduced post-task knowledge rating. Given the high error rates, it may be presumed rather than participants being successful in the task, the task in the present study failed to elicit the same awareness in individuals of their limited understanding.

There are several possible reasons the task in the present study did not elicit participants realisation of their limited knowledge. The drawing task in the present study was different to that of Rozenberg's (2021) and Lawson's (2006), (as can be seen in Appendix xxx). Lawson's (2006) task depicted a schematic drawing of a bicycle that included wheels, handlebars, and most of the frame components. To complete the task, participants were required to add pedals, chain, and additional frame components. In the present study, participants were provided with only the two wheels, and were asked to complete the schematic drawing, based on simple pictures representing the parts required to complete the drawing. It was believed that by requiring participants to draw more of the bicycle, the task would be made more difficult. However, when reflecting upon the results of the present study, the uncharacteristic results may be explained by drawing on Rozenblit and Keil's (2002) research. When they examined the IOED across knowledge domains, they found it to be unique to explanatory knowledge. In their experiments involving procedural and narrative knowledge, ratings showed no such drop in knowledge ratings from pre- to post-task (Rozenblit & Keil, 2002). Perhaps removing parts of the schematic drawing resulted in participants interpreting the task differently, in a procedural or narrative rather than explanatory function. Similarly, Ferbach et al. (2013) found asking participants to explain

why they held a political belief resulted in no IOED. However, when asked to explain a specific policy, participants displayed an IOED. Rozenblit and Keil (2002) described a feature of explanatory knowledge as having hierarchical levels of analysis, and this may contribute to the IOED, as people inaccurately judge to which level of analysis, they may understand a system to. It may be that the Lawson (2006) schematic drawing of a bike provides an initial level of analysis and prompts participants to contemplate deeper levels of analysis, whereas, perhaps, providing less of the schematic drawing may have prompted participants to contemplate only a shallow level of analysis. Thus, after which producing something that resembled a bicycle, believed their attempt of the task a success.

The increased self-knowledge ratings found in the present study may also be influenced by a participant group who were more familiar with bicycles than Lawson's (2006) and Rozenberg's (2021). Lawson's (2006) study participants reported 31% rarely cycled and 49% never cycled, in Rozenberg's (2021) 39% owned a bike. In contrast 57% of the present study participants reported to own a bike. Lawson's (2006) expert group (of whom frequently rode a bike), reported an increase from pre- to post-task like that of the present study. It is possible the participant group in the present study is more akin to Lawson's (2006) expert group. However, what contradicts this, is Lawson's (2006) expert group made far fewer errors than her two non-expert participant groups. The participants in the present study made a considerable number of errors, displaying error rates more like that of Lawson's non-expert groups.

The second hypothesis, which predicted no evidence of an IOED would be found in partner or dyad ratings of knowledge, was supported in the sense an IOED was not found. Instead, a similarly unexpected increase from pre- to post-task found in self-knowledge ratings was found. This hypothesis was informed by Rozenberg's (2021) findings in which no IOED was displayed in partner or dyad ratings. Previous research (Rozenblit & Keil, 2002; Sloman & Fernbach, 2017) has suggested the IOED occurs because individuals are mistaking what they can achieve with access to socially distributed knowledge, for what they can achieve alone. The dyad was created to be a form of socially distributed knowledge and thus participants may more "accurately" estimate their shared knowledge. However, the results of the present study showed partner and dyad knowledge ratings increased from pre- to post-task, similar to knowledge ratings made about the self. This contrasts with Rozenberg's (2021) findings. It is difficult to interpret the possible cause of these results given the uncharacteristic increase in knowledge ratings also found in self-knowledge ratings.

However, it is interesting to examine the significant interaction regarding knowledge ratings between Time, Target, and Group. Dyad knowledge ratings increased similarly over Time in the collaborative and nominal groups, however self and partner knowledge ratings changed differently over Time between the two groups. Those in the collaborative group showed a greater increase in partner knowledge ratings, than self-knowledge ratings. Participants in the collaborative group completed the task together, presumably learnt from this experience, and increased the knowledge ratings they gave to their partners. They however didn't increase their own knowledge ratings in the same way. Those in the nominal group showed a greater increase in self-knowledge ratings, than partner knowledge ratings. What is interesting here is that following the task, while participants in the nominal group increased their self-knowledge ratings, they didn't generalise this experience to their partner's knowledge. This may suggest, as previously hypothesised, people are using different decision-making processes for their own knowledge versus that of others.

The third hypothesis predicted individuals would give higher confidence ratings for self than partner and dyad knowledge ratings. It was thought that because individuals have easier access to estimations of their own knowledge, this would translate to greater confidence. Instead results showed individuals were equally confident of self and dyad knowledge ratings and showed low confidence in partner ratings. This was largely contributed to by a significant interaction effect between Target and Group. That is, the nominal group showed a much greater difference in confidence ratings between self, dyad and partner, whereas the collaborative group showed less of a difference. It is interesting that participants in the nominal group felt equally confident of their self and dyad ratings, while they had little confidence in ratings made about their partner. It may suggest participants weren't estimating dyad knowledge in an additive sense; that is, they weren't using the 'mental equation' self-knowledge plus partner knowledge equals dyad knowledge. Alternatively, perhaps people are aware of and practiced at accessing shared knowledge, thus feel a sense of fluency when recalling this knowledge, resulting in an equal degree of confidence as for self ratings. Given the unexpected IOED findings of the present study, it would be remiss to extrapolate significant meaning of these confidence ratings as an IOED was not present.

Other results found showed confidence ratings increased over Time, which appeared to be largely contributed to by a significant interaction effect between Group and Time. That is, confidence ratings increased dramatically from pre- to post-task in the collaborative group but only slightly in the nominal group. It may be that participants in the collaborative group,

by completing the task together, had evidence of their partner's bicycle knowledge. Thus increased their confidence in their partner, whereas the nominal group wouldn't have an opportunity to see their partner demonstrate their knowledge. However, it wasn't only confidence in their partner's ratings that increased; participants in the collaborative group held similar confidence in self, partner, and dyad ratings which all increased over time.

The fourth hypothesis predicted ratings made about the self would be faster than those made about partners or the dyad. It was thought individuals may utilize slower decision-making processes, requiring deliberation and consideration when thinking about the knowledge of other people than when thinking about their own knowledge. This is a possible explanation of Rozenberg's (2021) findings of no IOED for partner and dyad ratings. Instead, both knowledge and confidence ratings made about the *self* were significantly slower than those made about the partner and dyad. These findings may have been contributed to by a practice-like order effect, as ratings made about the self were the first participants made in both pre- and post-task ratings. However, a significant interaction effect was observed in speed of confidence ratings between Time and Target and a similar, albeit non-significant, interaction in speed of knowledge ratings between Time and Target. These interactions suggest that participants made decisions about the self slowly, and decisions about their partner and the dyad equally quickly. While an order effect may be partly contributing to this, it is interesting that participants appear to be considering the partner and dyad similarly, while assessing their own knowledge differently. It was predicted that people may employ heuristics when considering their own knowledge, thus making these ratings faster, albeit less accurate. The results of the present study suggest the reverse, although more research is required to understand possible mechanisms for this.

Pre-registered exploratory analysis

Task performance

In the preregistration the research question, "Will there be a difference in task performance between the collaborative and nominal group?" was posed. Drawing from collaborative recall literature, it was thought possible there may be both advantages and disadvantages to collaborating (Browning et al., 2018; Marion & Thorley, 2016; Rajaram, 2011; Thorley, 2018). Benefits might include cross-cuing and error pruning; that is, in working together, pairs are able to cue or prompt each other in recall and 'prune' or correct each other's errors. It was also thought possible there may be disadvantages to collaborating, termed *collaborative inhibition*, in which pairs working together recall less, maybe due to the

increased chance of interruptions when attempting to retrieve information. The results of the present study demonstrated collaborative *facilitation*, where collaborative pairs made considerably fewer total errors. When examining drawing errors and forced choice errors separately, the collaborative group made fewer errors across both. 15.8% of those in the collaborative group made 2 or more errors, whereas 73.7% of those in the nominal group made 2 or more errors. This supports studies by Vredevelt et al. (2019) and Vredevelt et al. (2017) in which collaborative pairs outperformed nominal pairs, in which pairs were asked to recall events for eyewitness testimony and error rates were factored into performance. This is interesting in that collaborative *episodic* memory recall research consistently demonstrates nominal groups outperform collaborative groups (Marion & Thorley, 2016). There are several possible reasons for this finding in the present study. Marion and Thorley (2016) found retrieval disruption was mediated by several factors including group size and relationship of group members. The group in the present study was a dyad consisting of two people who knew each other, perhaps reducing retrieval disruption. Wegner et al. (1991) also found non-stranger dyads outperformed stranger dyads when given no instructions on how to perform, suggesting their pre-existing TMS gave them an advantage. Additionally autobiographical memory by Harris et al. (2018) and Barnier, Harris, Morris and Savage (2018) and others finds collaborative facilitation. Interestingly, Rozenberg (2021) proposed collaborative inhibition contributed to her findings that length of relationship did not moderate the correlation between pre-task ratings and error rates. In part because her dyads collaborated online as research investigating online collaboration has found that online-based collaboration results in high rates of collaborative inhibition (Hyman et al., 2013). The dyads in the present study collaborated in person, and when compared to nominal dyads reported significantly fewer errors. The present study would support these studies in finding there are conditions in which collaborative pairs appear to outperform nominal pairs.

Relationship between knowledge ratings and performance

In previous IOED research the characteristic drop from pre- to post-task is generally interpreted as the participants 'recalibrating their judgements' and reporting a more accurate rating post-task (Rozenblit & Keil, 2002). Interestingly, few studies have examined whether either pre- or post-task ratings are an accurate representation of participants' knowledge as measured by performance on the task. Lawson (2006) and Rozenberg's (2021) are the few who studied correlations between knowledge ratings and performance (errors). Both Lawson (2006) and Rozenberg (2021) found that self-assessed knowledge (ratings) did not correlate

highly with actual knowledge (error rates). The present study was novel in that it was a between-subjects design and aimed to contribute to the research examining this relationship between self-assessed knowledge and actual knowledge. In particular it did this by examining whether individuals were more accurately assessing their individual knowledge or socially distributed knowledge within a dyad, as suggested by IOED literature.

Thus, in pre-registration the following additional research questions were posed:

- Will individual pre-ratings predict nominal or collaborative group performance?
- Will dyad pre-ratings predict nominal or collaborative group performance?
- Will nominal group performance predict individual or group post-ratings?
- Will collaborative group performance predict individual or group post-ratings?

Overall, the results of this study showed little correlation between pre- or post-task ratings and performance in either the collaborative or nominal group. Each research question will be discussed below. The results of a Pearson's correlation showed no significant relationship between self pre-task ratings and total errors, drawing errors, or forced choice errors in either the collaborative or nominal group. This indicates that participants were generally inaccurate when estimating their knowledge of bicycles. This is consistent with the results of Rozenblit and Keil (2002) and Lawson (2006).

Dyad pre-task ratings in the nominal group had a significant correlation with dyad performance errors, indicating, perhaps, that dyads in the nominal group had some understanding of how much knowledge they held between them. This result might suggest that, as predicted, individuals are more accurate at estimating knowledge held within their TMS than their individual knowledge. However, this is the case only when working alone on the task, the collaborative group showed no such relationship between dyad pre-task ratings and errors. It seems something about working on the task together reduces participants ability to predict how they will perform on the task. Research into couples as socially distributed cognitive systems demonstrates both benefits and costs to collaborating dependent on the communication strategies participants used (Harris et al., 2018, Harris et al., 2014). In the present study collaborative dyads performed better on the task than nominal. It may be that the complicated nature of communication makes performance more difficult to predict, even if the participants know each other well. In the case of the present study participants in the collaborative dyads may not have accounted for the benefit from error pruning. This might

suggest participants made judgements about how the dyad would perform under the assumption there will be a perfect ‘summing’ of the performance of the individuals.

Rozenberg (2021) found that while individuals changed their mind about their own knowledge, they did not change their mind about their partners or the dyads knowledge. It may be that individuals in Rozenberg’s (2021) study had a more accurate pre-task understanding of their partner’s and dyad knowledge than of their own knowledge and therefore had no reason to change their ratings of partner and dyad knowledge after the task was carried out. Coupled with the present study’s findings that dyad pre-task ratings were correlated with errors, this tentatively supports the theory the IOED occurs because individuals are mistaking what they can achieve in a supported social environment for what they can achieve alone. However, it is important to acknowledge further research is required to examine this relationship before any conclusions can be drawn.

Self post-task ratings showed little to no correlation with errors in either the nominal or collaborative group. As previously noted, this suggests that people are generally inaccurate at ‘recalibrating’ their own knowledge judgements after having a chance to use that knowledge. By contrast dyad post-task ratings made by the nominal group showed some small non-significant correlation with errors. This is consistent with the relationship found between dyad pre-task ratings and errors. This suggests that participants are more accurately recalibrating their knowledge, only when considering their shared knowledge, rather than their individually held knowledge. However, as was the case for dyad pre-task ratings, collaborative participants showed no relationship between dyad post-task ratings and errors.

In summary, it appears neither self nor dyad ratings show a consistent pattern of correlation with error rates in either group. This study highlights a concern with using correlations as a means of examining the change in participants judgements. Correlations do not measure how accurate participants are at assessing their knowledge, rather the strength of relationship between error rates and ratings. Even if correlation were high, this only indicates that as participants ratings increase so too did their performance. Conversely participants may be systematically inaccurately predicting their performance. In one study by Rozenblit and Keil (2002) independent participants were asked to rate the explanations given by previous participants. These independent ratings were found to be much closer to later self ratings of knowledge than initial self ratings by participants, thus implying participants had become more accurate at measuring their knowledge. Future research could consider including independent ratings of participants as Rozenblit and Keil (2002) did. Therefore, while considering the limitations of correlating knowledge ratings and errors as in the present study.

It may be concluded participants are generally poor at assessing their own knowledge or that of the dyad, whether they are working collaboratively or alone.

Further research is required to explore this relationship between people's judgement of knowledge and performance of the group, and how this is influenced by the act of collaboration. The study's results were inconclusive regarding how people make judgements about the performance of the group. It seems in some respects collaboration made it more difficult for participants to predict performance of the dyad, in other respects the dyad ratings were the only knowledge ratings correlated with performance. It may be that by its nature a collaborative environment will be a more complicated one to predict. Given 'calculating' the groups knowledge using a perfect 'summing' of individuals performance is much simpler, perhaps there are conditions under which this is helpful. This study provides a base for future research to more closely examine how people make judgements about the group.

Practical and Theoretical Implications

The present study built on the exploratory research of Rozenberg's (2021) and itself remains exploratory. Furthermore, the findings were seemingly at odds with the findings in much of the IOED literature. Considering these two factors, this section will aim to explore possible implications of the present study.

An important theoretical implication arises because of the finding that knowledge ratings increased from pre- to post-task, as opposed to the characteristic decrease, despite considerable error rates. These findings may indicate the IOED is not as reliable as previously expected. However, as there is considerable research evidencing the validity of the IOED, it might be easiest to assume that the changes made in this study to the bicycle task, meant it didn't function as an explanatory task. If the bicycle task in the present study didn't function as an explanatory task, it may not have triggered the characteristic reflection by participants of their limited knowledge. Despite not finding the typical reduction in knowledge ratings, the present study nevertheless contributes to the IOED literature. It supports previous research demonstrating participants' poor ability to accurately assess their individual knowledge. It is novel in that it highlights the sensitivity of the IOED testing paradigm and consequently how difficult it is to elicit awareness of the limits to people's individual knowledge.

A practical implication of the findings may be considered in the context of COVID-19, and the task governments and communities have in combating misinformation. COVID-19 has highlighted how rapidly in the age of social media, misinformation can spread. Vitriol

and Marsh (2018) found a political IOED was associated with increased support for conspiracy beliefs, both general and election specific. It may be, as with other complex theories requiring causal knowledge; people are inaccurately assessing their knowledge of the scientific principles underpinning viruses and vaccines. Fernbach et al. (2013) demonstrated that, only when people are asked to think about the mechanisms rather than reasons for their political opinion, do they become aware of their limited understanding, resulting in reduced political extremism. Although Crawford and Ruscio (2021) were unable to replicate these findings, Sloman and Vives (2022) found a reduction in both a sense of understanding and political extremism when participants were asked to explain policies. This reduction was only demonstrated for issues that lent themselves to a consequentialist perspective, where participants were forced to consider potential outcome of policies, such as sanctions. Whereas it was not found for issues that elicited sacred values, such as assisted suicide. In the case of combatting COVID-19 conspiracies, it will be essential to prompt people to think about the mechanism of the science underpinning their conspiracy beliefs. The findings of the present study highlight the importance of ensuring causal explanations are included in information and discussion. The present study suggests if framed in a procedural or narrative sense, it is unlikely to result in someone becoming aware of the limit to their own knowledge and may risk increasing their perceived knowledge. This is an essential consideration because as Fernbach et al. (2013) found, this awareness of their limited knowledge, not only softened participants political extremism but also resulted in behaviour change.

The present study appears to be the first to ask participants to rate their confidence in their knowledge ratings. As the findings of this study contradict previous IOED research, it may be inappropriate to apply the findings regarding confidence ratings to the IOED literature without first acknowledging the limits of this. However, there are several interesting questions that arose from this study that may inform future IOED research. Those in the nominal group showed equally high confidence in their knowledge ratings about the self and the dyad but not their partner. This supports Rozenberg's (2021) finding that participants are not simply 'calculating' ratings by adding together self and partner information to a sum which represents the dyad. Instead, they appear to be thinking about dyad ratings in a different way. Those in the nominal group showed the same degree of increase in knowledge ratings from pre- to post-task as those in the collaborative group. However, reported little increase in confidence ratings over time. While collaborative dyads may have greater confidence in their partners after completing the task together, it is interesting to note that nominal dyads reported increased knowledge ratings for their partners but not confidence. As

mentioned earlier, it would be interesting for further research to examine how people may use different methods of decision making about individual and shared knowledge in collaborative and nominal groups and examining confidence ratings may be one way to do so.

The findings of the present study showed it was beneficial to complete the task which required explanatory knowledge with access to a TMS. Importantly in a situation where error rate is the key measure of performance. The practical implications of this are already being explored in eyewitness testimony situations (Vredevelde et al., 2019; Vredevelde et al. 2017) where accuracy of recall is paramount. There are several fields which require professionals to utilise explanatory knowledge that these findings may have practical implications for. These include medicine, where it highlights the importance of patients having a support person with whom they can recall their medical history. Similarly in a military or surveillance setting, any debriefing where accuracy of recall is paramount, it may be helpful to complete this within the framework of a TMS. Given these fields may have existing structured methods for debriefing, such as an evidential interview, further research is required in the context of these methods.

These results also have implications more broadly for collaborative memory research, suggesting consideration is required when designing research. Much of the collaborative recall literature comparing nominal and collaborative groups focuses on correct recall, rather than error rates. While the collaborative recall literature identifies both benefits and costs to collaborating on a task, there is only a small research base examining the impact of collaboration on retrieval errors (Marion & Thorley, 2016). This implies further research comparing collaborative memory in nominal and collaborative groups should carefully consider what it is they're trying to measure and thus whether to measure correct recall, error rates, or both. Further research is required to better understand errors in collaborative memory.

Shortcomings

Several limitations, additional to those already discussed, may challenge the utility of this study. Shortcomings mentioned previously include the sample size and the limitations of using correlations between knowledge ratings and errors. Further limitations of this study include it being conducted online, use of knowledge rating questions, and assuming a dyad represents a TMS in the natural environment of which we typically explain how things work.

At the time of designing this study, Aotearoa New Zealand, in particular Auckland, was experiencing sporadic and recurrent lockdowns due to Covid-19. To ensure the research

could continue should there be a lengthy city-wide lockdown the study was carried out online. Online research has unique limitations, some of which apply to this study. It typically limits the sample representativeness, as automatically only those with access to a device and sufficient internet connection were able to take part. This is likely to disproportionately reduce participation by those in lower socio-economic groups. Quality of the data is another concern for internet-based research, although given clear instructions, it wasn't possible to know whether those in the collaborative group completed the questions alone or not. Online research typically can't engage participants for as long as in-person lab-based research. The present study was at the end of the spectrum (15mins) of which participants are reported to answer questions thoughtfully. It is difficult to estimate the effects of the study being conducted online.

Although the present study built on two studies that used this bicycle task, one limitation that seems apparent is it is unclear how participants are conceptualising the knowledge rating questions. Therefore, it's unclear how reliably this can be utilised as a measure of participants' judgements of their explanatory abilities. The instruction given to participants was to "rate your knowledge of bicycles from 1-10". It is unclear how participants may be interpreting this first question; however, they are unaware the task will involve drawing a bicycle. Thus, it is unlikely to represent their perceived performance on the task ahead. Whereas it is likely that post-task ratings represent participants perceived performance on the bicycle task. This may limit the ability to correlate the two as a measure of change in perception of explanatory knowledge. It also limits the ability of studies using this method to understand possible mechanisms underlying changes from pre- to post-task ratings.

A limitation raised in Rozenberg's (2021) study that was unable to be resolved in this study was the reliability of correlating knowledge ratings with performance on the task. Several possible methods were explored such as use of a tally system and alternative statistical analyses however no alternative methods of measuring this accuracy of prediction was found. As mentioned earlier, correlations measure the systematic variation or relationship between two variables, which is helpful when initially exploring the possible relationship between knowledge ratings and error rates. It doesn't however imply accuracy; it may equally likely demonstrate a systematically inaccurate judgement.

In the present study, the dyad was assumed to be representative of a TMS. It may however not have properly reflected the TMS people typically access in a natural environment. In real world examples, people are likely to have much greater access to a

wider network of socially distributed knowledge. Additionally, while TMS reportedly develop with time and experience together, that is, more experience being a group and sharing memories, the more efficient the TMS is likely to be (Barnier et al., 2014; Harris et al., 2011). It is crucially also dependent on the TMS utilising efficient communication strategies (Harris et al., 2011) and length of relationship doesn't necessitate a strong and efficient TMS (Peltokorpi & Hood, 2019). So, despite the majority of dyads knowing each other for 2+ years, it may not be representative of the knowledge systems people typically access when making explanations.

Future research

Further research is required for several reasons, one being this study is exploratory and only beginning to explore and understand illusions of knowledge in more than just individuals. This is the first study to examine the IOED in TMS using a between subjects design. The present study aimed to partially replicate and expand on Rozenberg's (2021) study. Considering the unusual IOED findings that contradict much of the IOED literature, there is a clear need for additional replication and further research, as well as understand the mechanism by which an increase in knowledge ratings was observed. This might involve timing participants ratings again, while accounting for order effect by alternating the knowledge rating orders. Given it can be hypothesised the task in the present study didn't function as an explanatory task, future research could examine timing and find different results.

Future research should carefully consider the task used in IOED research, as made clear in the present study it may be easy for participants to misinterpret tasks as procedural or narrative. One method to alleviate this, that should be considered, is training participants prior to the task. Studies such as Rozenblit and Keil (2002) implement this by having practice or training questions in which participants learn to judge levels of explanatory knowledge on a 7-point scale.

As both the present study and Rozenberg's (2021) study was conducted online, future research should consider conducting in-person research. This would enable researchers to record and examine decision-making processes within the pair and understand more about how recalling within a TMS is beneficial. There is significant research evidencing collaborative inhibition and closer examination of the communication between collaborative dyads would give insight into how it is they are avoiding collaborative inhibition. This might involve recording of their communication to enable coding later, to understand how error

pruning occurs or why retrieval strategies aren't disrupted. There would also be the additional benefit of understanding participants subjective experience of the IOED paradigm.

Conclusion

Contrary to much of the IOED research, results of this study showed individuals self-assessed knowledge ratings increased from pre- to post-task, despite high error rates on the bicycle task. Nevertheless, it supports the IOED literature in demonstrating how poorly people assess their individual knowledge. This study initiated exploration into the mechanisms that may underly IOED's existence or lack thereof, in TMSs. The results tentatively suggest participants experienced a feeling of fluency and possible accuracy when considering the shared knowledge within their TMS. Given the notable results found concerning the dyad, that being shorter speed of judgements, high confidence ratings and correlation with errors. Although the results did not replicate previous research as it set out to, the study will inform future research examining the IOED. Further research is needed to continue exploring the effect of collaboration on socially distributed knowledge. It is suggested this is done so through examining the communication between the individuals within the TMS.

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